SEYMOUR CRAY ORAL HISTORY

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Transcript of a Video History Interview with Seymour Cray, Founder of Cray Research

Recipient of the 1994 MCI Information Technology Leadership Award for Innovation

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Early Interest in Science and Engineering

David Allison (DKA): Seymour we wanted to start with your background, your schooling, how you got interested in science and engineering. You were born in Chippewa Falls. Did you go to school there?

Seymour Cray(SC): I went to grade school and high school in Chippewa Falls. Just as I graduated from high school in 1943, you know what happened so I was packed off to the army. It was probably three or four years before I got finish my college life so to speak.

DKA: Were you interested in science in your grade school and high school?

SC: I was one of those nerds before the name was popular. I spent all my time in the electrical engineering laboratory and not enough time socializing as I viewed life later.

DKA: So you had been interested in electronics from as well from an early age?

SC: Yes.

DKA: Were one of those who were playing around with radios? Was that the type of electronics you did?

SC: Radio and electrical motors, electrical circuits, electrical things of all types. At that point in time there really weren't computers. That name didn't enter the scene until just about the time I graduated college, 1950, 1951 timeframe.

Discovering Digital Computers

DKA: Did you enter into electrical things as a hobby as well? Did you make things around the house?

SC: Yes. I explored everything that I could with the limited financial resources I had at that time. During my college days I concentrated on things that were digital and digital things in those days were not comprehended as being computers. They were just elementary circuits that had two states and so it wasn't until after graduating from college that I appreciated that there was a whole world of digital computing.

It is fun to remember that point in time in one's life when you get your degree, you stand on your corner of the street and you ask yourself "What's next?" For me, I was fortunate in having an instructor at the University of Minnesota who was looking after me in the sense that when I said "What's next?" he said, "If I were you I'd just go down the street here to Engineering Research Associates and I'd think you'd like what they're doing there." This turned out to be one of the very first computing facilities in the sense of developing digital circuits.

I did that and it was fascinating for several reasons. One of them, the building itself which was an old glider factory and when I heard this, I thought who in the world would make gliders? As I looked around this was a woodworking facility, very large hangar. This was a part of the plan for the D-Day landing in Europe and the plan was to build in St. Paul, Minnesota large numbers of wooden gliders that would be pulled by a single airplane in a long train across the English Channel and then come gliding into France. So this facility was built for that one purpose.

They did make a large number of wooden gliders and I believe some of them were used in the D-Day landing but I think they were not very significant. There were people parachuting. There were people gliding. I think we did just about everything we could think of to get people ashore at that point in time. In any case, here I went to work in a wooden glider factory and they were making computers.

The Name Cray

DKA: Before we get into that, what are the origins of the name Cray?

SC: Origin of the name Cray? It's a small community in England. So the name is English. There are very few Crays in the United States. I've occasionally looked in telephone books as I visit a large city and have a moment in a hotel room. There are usually one or two in a million population city. It's an unusual name. I'm pleased with it because there are only 4 letters and it doesn't take very long to spell it when you have to spell your name.

DKA: We talked about your father off tape. I wonder if you could repeat just for the tape, a little bit about your dad and what he did and how that might have affected your own career.

SC: He graduated from the University of Minnesota as I did. As a civil engineer, went to work for the Northern States Power Company, which is the electrical utility still in that area. Went to Wisconsin because at that point in time there was a perception that electricity should come from waterpower and there was a river flowing through Wisconsin that joins the Mississippi River in the south corner of Minnesota and Wisconsin. It's called the Chippewa River. And so at that point in time the Northern States Power Company built a series of dams to get the absolute most electrical power they could get form this river. There were four or five such dams. So his early career was surveying for the sites for the dam, defining how big the water would be behind the dam and dealing with the engineering issues at that point. He liked the area so after the dam was completed that he was working he stayed as the engineer in this small town. City engineer.

DKA: You had mentioned that he had a variety of functions in that job.

SC: Yes he did most of the department functions for the city. He was the plumbing inspector, the electrical inspector, the building inspector, and probably a number of other inspectors and so if someone built a house in town he could pretty well take care of you with one stop.

DKA: There's a sense of completeness that's been part of your career in some ways mirrors your father's having to deal with a whole set of issues.

SC: Yes he certainly was "a thing" oriented person instead of human oriented person. The technical person as distinguished from the social person.

DKA: What about your mother? Was she a balance to him?

SC: I thought she was. She certainly provided a little bit of social contact for him in his life. I only ask the same of my wife now. Take me out on the town once in a while. But not too often.

Experiences in the Service

DKA: You mentioned that you spent some time in the service. Did you do electronics work in the service?

SC: Only at the very lowest level because being reluctant to get into the service, I ended up in the infantry. In the infantry you don't have a lot of electronic equipment around. I did end up in a communication platoon so I carried around a walkie-talkie and I pulled wires through the jungle and things like that. I had the opportunity to visit both theatres.

I arrived after D-Day in Europe but I did get to see the Battle of the Bulge and tramp my way through Germany to meet the Russians. Then I went over to the Philippine Islands and finished up in the Pacific. That was a real experience because I was in the middle of the jungle and I was supporting the Philippino Guerilla army who were routing out the remnants of the Japanese Navy. It was, as you can imagine, an interesting experience to see these 17 and 18-year-old Japanese kids coming out of the jungle after living on bananas for 2 or 3 years. That was my wartime experience.

DKA: I've read quite a lot about the navy history in the Pacific and the difficulties they had keeping their equipment work because of the conditions. I don't know whether you saw much of that. The material wasn't tropicalized for those conditions.

SC: We learned a lot in terms of technology during that period of time to deal with things like salt water. It wasn't my area because I was on land all the time but I saw the results of it afterwards.

Joining Engineering Research Associates

DKA: You came back and finished college?

SC: 1950 and 1951. I got a Masters degree in applied mathematics between 1950 and 1951.

DKA: You were saying that you weren't quite sure what you were going to do. Had you done a lot of work with electronics in college?

SC: Yes, but I had no idea what kind of business that would lead to. It was just a fortunate coincidence that I ended up at the beginning of computing. At the time, I joined Engineering Research Associates the facility was one year old. It was sponsored by the Navy to build cryptographic equipment. This was one of two or three original motivations for digital computing. People like Pres Eckert of course were doing ballistics for artillery but there weren't very many, maybe two or three different groups, each with a particular narrow mission. But I was in the intelligence part of it.

DKA: What were they specifically hiring you to do? Were you working on circuits or did they have a specific assignment when they hired you?

SC: Well, we were building computers. The very first machines I worked on were the beginning of the 1100 series computers for what ended up being Univac.

DKA: Tell me about at ERA atmosphere in those days.

SC: It was the blind leading the blind. There were people all hired within a year because the facility was only that old. There were perhaps a dozen navy people who had some idea about the purpose of the whole project but were most were very young people and at that point in my time and knowing nothing about computing equipment I spent a good deal of time in the library reading what material there was, almost all from universities of an academic nature as to what computing should be and how it works. I quickly discovered in a few months that there wasn't much there. It was onto invent from that point. It was a wonderful opportunit to get started without a lot of peer pressure in the sense of there wasn't much of anybody else there.

DKA: You became familiar with the work of Eckert and Maucley and the Morris school lectures. I don't know whether you read any Von Neumann.

SC: MIT yes. Von Neumann did visit there. I remember him I think on two occasions visiting.

Working Style at ERA

DKA: You were quite known over your career for your particular style of work. Had that developed at that time? Were you already jumping into becoming a designer of circuits and how did you tend to work at ERA?

SC: I did tend to work alone doing work primarily in the evening when I wouldn't be interrupted by other people. That lends itself to computer design because it’s hard to do it as a group activity. Having started down this road it ended up going for a whole lifetime; one machine leading to another machine.

I guess to summarize it early on, I got my understanding from other designers but later on it was more feedback from people who used the machines. For the last 30 or 40 years I've been getting my insights from the customers who bought the Cray computers. They would tell me what's wrong with it. I'd address those issues and we'd go another generation. It's been very evolutionary. Essentially every machine I've designed since that first day has been a clear descendant of one another in their structure.

DKA: You were given an assignment to do a full design of a computer at ERA?

SC: I was part of a design group initially. After I think probably two machines then I was on my own so to speak, having control of the design.

DKA: And that was still when you were at ERA?

SC: Yes. The lifetimes of machines were very short in those days, like six months.

DKA: What was that first one that you did by yourself?

SC: The 1103 Computer.

DKA: When you say you started a tradition of machines, was it related to that particular one?

SC: Well it certainly was the beginning of my structuring machines as I thought they should be. As I say with feedback from customers from that point on in terms of what changes to make from one machine generation to another.

DKA: How would characterize the principles of that? The vision that you had of the 1103?

SC: My guiding principle was simplicity. I think there is an expression for that. Don't put anything in that isn't necessary. Whereas many other places at that point in time and for several years after that were adding all the bells and whistles that could be imagined. Later on much more recently there came the term "RISC" which says "back to the basics", make it as simple as you can. I thought I was a RISC person all the time even though I didn't know the name.

The Importance of Speed, and Generations of Components

DKA: Did you find that that was unusual in terms of the people you work with at ERA? Did you find yourself taking a different track from ones that others around you were taking?

SC: No. I don't think so at that point in time. The goal was to make something quickly. Time was the most important element. There wasn't a competitive aspect at that point in time as there were later on with companies competing with one another. At this point in time there was no competition. This was the only project doing digital computing for this application.

DKA: Was speed equally important in your work at the ERA?

SC: Speed has always been important otherwise one wouldn't need the computer. It was the dramatic change from hand calculating to electronic calculating which was the first step and then from that point on its mostly has been related to improvements in memory because memory has dominated the speed of computation throughout these decades.

DKA: You worked in a tube based environment at ERA.

SC: That's right. I had the opportunity to go through a whole series of circuit evolutions starting with vacuum tubes, which were World War II kinds of things for digital purposes. Then there was a phase called "Magnetic Circuitry" and I enjoyed that very much. It was a very short lived set of circumstances. I would guess less than 10 years that magnetic circuitry was competitive and then it was superseded by the transistor. There were three generations of basic components. All equally interesting.

DKA: I think you also ran into some people that you would later work with in other parts of your career. Who do you remember from that time period?

SC: Well there were people there who ended up a whole lifetime later in terms of products starting at Cray Research with me. Names like Frank Melaney and George Henson who both date to ERA days. James Thornton is another one who is a principle at that point in time in computer design. When a group gets started as they did at this particular point in this glider factory and then they spread into many different companies, you see the same names and faces in a variety of situations. That's still true as I look around today as the massively parallel companies, we've had a variety of in the last five or six years. If you look at who is running the company, its still the same group of people. It's almost like family in a sense. You recognize names and faces from long ago.

DKA: Did you find that, in terms of the vision of the computer business that people separated themselves out fairly early or that you had a clearly shared idea in that early period?

SC: Clearly there was a separation between the people who liked to do the technical work and the people who liked to supervise other people. It has been a struggle for those supervising in our business and I suspect it is not at all unique but there has been too much of a feeling that you want a technical person as your supervisor which is too much to ask generally. Technical people make poor supervisors therefore you shouldn't want one. But people still do. It's been a dilemma in terms of running organizations to find the right compromise between management people who are technically oriented and those who have management skills.

DKA: You stayed at the ERA for a couple of years and then later went on to work for Remington Rand.

SC: Same place. Same spot. It was an acquisition of ERA by Remington Rand, later an acquisition of Remington Rand by Sperry and after I left an acquisition of Sperry by Burroughs and now called Unisys but there is still the basic continuity of people and product through those various stages.

DKA: When ERA was bought out, did that change the work style of the company or your work style and company projects that you got?

SC: Yes.

DKA: How would you characterize it?

SC: At that point in time, Remington Rand being a commercial typewriter company, it was their purpose to take this facility and make something commercial out of it. The emphasis changed from the military dominated part, which I was in, to making new products for industry, which of course is a pretty serious transition. My part in remaining in the military area rapidly diminished and just before I left, I thought I got the clear message when I found an accounting system; my project was under "999 Miscellaneous and Other". So I got the picture I wasn't mainstream anymore. That was the point where I left with Bill Norris and started Control Data Corporation.

Decision to Build Scientific Computers at CDC

DKA: Clearly that was one of the major decisions of your life. How did you come up with the idea?

SC: Those things are easy because there seems little choice at those points in time. I didn't start Control Data. I mean I wasn't part of forming the corporation. I was probably the most technical person to begin with the company. I had a clear idea of what I wanted to do which was to build large scientific computers. The rest of the half dozen or so founding people thought that they should go into commercial activities, like point of sale machines which was a generation or two, or a decade or two before those things were really practical and I said "No, no, no. I'm going to build large scientific computers." And I proceeded to do that.

So that's what happened to the company. We ended up building large scientific computers and quickly took over I would say, that particular market from the company we left. It was interesting to see how, over periods of a few decades, the world perception of need varies so widely from "there's no more need for large computers to we've got to have large computers to there's no more need for large computers".

There have been several cycles of this. We're going through one right now in the sense that currently in the United States at lease and in the U.S. Government, the perception is that microprocessors are so powerful there's no need for anything else. Anything else that needs to be done can be done with microprocessors. So we're seeing great efforts being made to accomplish that goal, massively parallel arrays of microprocessors. Perhaps it will succeed but it presents a lot of software difficulties that we're struggling with today. Its not clear to me that in the long run that it will turn out the best way to do it.

Starting Control Data Corporation

DKA: It's fascinating and we'll get back to that later. I'd like to go chronologically because there are so many interesting areas to focus on. I'm particularly interested in this formation of CDC. That was around 1957?

SC: Yes, I believe so.

DKA: You were still quite a young man. Was the generation from Bill Norris? Was he the...?

SC: He was the president and he was the leader in the sense thought that if Bill Norris was doing this, it was probably okay. I wouldn't have needed that, because I knew what I wanted to do anyway. It wasn't quite what Bill Norris wanted to do but nonetheless we had no difficulty getting along together. He was anxious to see a company succeed.

It's interesting to look at monies in those days of course, looking back you always have to think about the value of money. The company raised $600,000, which was a huge amount of money in those days. It was done in a way that we can't do anymore. It was done on the street corner where people would stop by and say, "Oh, what are you selling?" And you'd say "Oh, we're selling stock in a new company and it's a dollar." And people bought a few dollars here and a few dollars there. There were no large investors in Control Data Corporation. I risked most of my assets. $5,000 dollars I invested which was a huge sum of money. It turned out to be a much bigger sum of money. It is interesting how our protective mechanisms over the years prevented such wild things from happening. Now it takes you six months to get approvals to do start any kind of an operation.

DKA: There was a notion here, why the compelling reason to build computers for science? Why science?

SC: Science is something that I'd always had been interested in and I thought understood. Having the narrow focus of striving to perfect in a particular area, the scientific portion of computing is what appealed to me. I thought I could deal with that issue. I could understand the goals and direct my efforts towards that. Its certainly true that for my life as a designer of equipment its been narrowly focused on scientific computing to the exclusion of all the other opportunities that existed.

The Style and Vision of Working with Computers

DKA: Were you driven by a vision of the objective or a vision of the elegance of the machine itself?

SC: I don't think I'd use either of those terms. I was driven by the fascination with making improvements in the tools that were available. I enjoyed doing the work. The work was a goal in itself for me. The fact that I saw benefit to society and I got positive feedback from the rest of the people that I worked with all encouraged that. But basically I enjoyed doing the work. The fact that this could be done repetitively generation after generation and still be a productive kind of activity I found very satisfying.

DKA: What is your style of work? Put yourself back in the situation of CDC and you have this objective of designing a scientific computer. You have an idea. How you carry that out? How do you work?

SC: If we skip the very beginning which was a learning process for me, then from that point on it was a matter of getting feedback from customers using the previous model, hearing the complaints, the wants for the future, attempting to understand what they are and how they might be implemented and working alone for the most part in structuring the computer architecture to meet those goals.

I of course, needed a lot of support people to implement the ideas but the basic concept I thought could not be and should not be a group effort. Designing by committee is not appropriate for computers. You pretty much need one person to say, "This is the way it's going to be for this machine." And when that machine has been completed and delivered then you can reassess well what should the next machine be? Its important early on to have a clear definition of what the goal is. It has to be realistic in the time frame and in the financial restraints that are there for that particular point in time.

DKA: Seymour, with that said, what is the connection between goal and risk taking that you spoke about?

SC: Goal and risk taking.

DKA: You spoke about the risk.

SC: Well risk taking of course, is any time you try to do something that hasn't been done before, you have the risk of failure. That can take several different forms. The risk of failure to oneself and not being able to accomplish the goal. The risk of failure to other people who are relying on you. Guilt, I think that would be called. The risk of running out of money and being embarrassed because you didn't keep to a schedule. All of those are aspects of risk taking as I see it. They have little to do with the goal, except the goal provides you with the motivation for the risk taking. I guess that would be the way to say it. There has to be a goal or you wouldn't be taking a risk.

DKA: Your goal at that time was to design a fast scientific computer - faster than anything that was available.

SC: That's correct.

DKA: Fast in the sense of doing multiple floating...Did you think of floating point operations at that time?

SC: Well floating point operations came along mid-life. It wasn't a crisis, but it was mid-life. There's more than just speed. Certainly for the last several decades there has been cost effectiveness and that has become more and more important until today cost maybe more important than speed. So to make a machine that's cost effective, allows you to succeed in the marketplace and therefore go on to the next generation.

DKA: You said you wanted to design the whole architecture yourself. A single person. What were the limits of that? Did that include all aspects of the single processor? Did it include everything down to the peripheral units? How did you see the product in terms of what you yourself had responsibility for?

SC: To my mind, the goal of the single person leading the product would be to define how the machine is going to work. What are the instructions in the computer? How big is the memory? What is the memory made of? And then other people can take a portion of the technical work that needs to be done and work within those constraints. It is an architectural overview that I think a single person has to provide.

DKA: We were talking a while ago about designing at CDC when you first got started. We know that your goal was to design fast scientific computers. Was it a scary time in terms of being able to meet an objective that would deliver and keep the company in business?

SC: It was scary but not at all what you expect. And so I'll enjoy telling you this part. The scary part was that we were trying to start a company with virtually no money and accomplished the construction of the world's biggest scientific computer and do it quickly. And so the environment was the threat.

There was a large newspaper in Minneapolis and probably still is. The Minneapolis Tribune I guess it is. And so we were in the paper warehouse where they store these large rolls of newsprint. They were stacked up about four rolls high in this big warehouse. I did my engineering work in one corner and at night I could hear the rolls slipping every once and a while and there was a block of wood under the end roll and so my fear was that the block would slip some night and all those rolls would come down on me and I be squashed against the far wall.

This was a period of time for probably one year but I shall always remember the sound of those rolls of newsprint slipping every once in a while and it would sort of echo through the empty building as I was busy working on my computer in the corner.

DKA: So were you also alone at night?

SC: Yes. Very much.

DKA: Its always said of you that you liked to start with a clean piece of paper and draft.

SC: I had a good supply there.

DKA: There is this connection about the creative relevance for you between always having a blank sheet of paper and starting from that. Can you help us understand that?

SC: Well you have to understand that the blank sheet of paper is not a blank mind. I wanted to take advantage of all the things that I remembered and all the inputs I had gotten from people over a period of a few years to help me to decide what to make.

But by the blank piece of paper I mean that I liked to start over with the technical details, review all the things that the world offers at this point in time rather than to reuse things that were just used. I would rather try new ingredients in building the computer than old ingredients. That is what I meant by the expression "a blank piece of paper" for each design. This of course gets one in trouble because it increases risk. Every time you take a new approach, new ingredients, you increase risk. But it was my feeling that the rewards would come often enough so that taking those kind of risks would have long term benefit. I think they did during my career.

The Transistor Innovation

DKA: What was new when you were at CDC? What was the new innovation that you were trying to maximize?

SC: It was the transistor. This was the time the transistor first appeared on the scene. Again, a part that I enjoy remembering was transistors were very expensive in those days because they were new. At this point I'm just beginning the Control Data 1604 Computer. It was the first computer for that company. The goal was to make this as quickly as possible at the least cost. I discovered that the local retail store in Minneapolis was selling reject transistors at a very low price compared to what you buy from the factory. I was able to buy all of them that they could get. After a few months, I was visited by the company representative who said, "I'm sorry but you've used all the rejected transistors we have and we can't afford to sell you the new ones at that price". I had exhausted the entire world supply of reject transistors for transistor radios in building my first computer.

DKA: But they were good enough for you.

SC: It's possible to design around such things by choosing your circuit to be very tolerant. Its possible to use substandard components and still accomplish the goal. Its one thing I could remember for a long time after that. You don't necessarily have to have the world's most components to accomplish a goal you can design around things that are less perfect.

DKA: The 1604 was transistor based. How successful was it in the marketplace?

SC: The only competition at that time was early IBM machines still based mostly on punched cards. The 1604 was very successful in the scientific market. It was because of its uniqueness. It was the first large scientific computer that was transistorized. IBM was the competition shortly thereafter but IBM was always one step behind in terms of technology much to the frustration of IBM management people.

DKA: You went from the 1604 to the 6600?

SC: 6600 and 7600 were the follow on machines that were all evolutionary. They were each very successful.

DKA: Characterize the difference for use between the 1604 and the 6600.

SC: It was simply evolution, feedback from customers, building a more capable machine at each step. Very evolutionary.

DKA: Was memory the issue?

SC: Memory was the dominant consideration; how to use new memory parts as they appeared at that point in time. There were, as there are today large dynamic memory parts and relatively slow and much faster smaller static parts. The compromise between using those types of memory remains the challenge today to equipment designers. There's a factor of four in terms of memory size between the slower part and the faster part. It’s not at all obvious which is the better choice until one talks about specific applications. As you design a machine you're generally not able to talk about specific applications because you don't know enough about how the machine will be used to do that.

Early Scientific Computing Requirements

DKA: You mentioned that you dealt with scientific computing. Your customer base however extended both to universities and to government as a whole at this time did it not?

SC: I don't think there has been much use other than scientific for the types of machines I've made over my career. That of course, has become a very large market. Science does dominate a lot of computing today. I never made a machine that was good for accounting or for any inventory control really. Cray Research for example, may sell a few machines in those areas but they are a very small portion of the total sold. That has been IBM's mainstay.

DKA: Seymour, how would you characterize the world of computing in the mid-60's? We're talking now of the 6600, the mid-60's. The computer had been fairly new. It was now spreading. How would characterize this world of customers that you were trying to attract?

SC: As I perceived it the scientific community was just discovering that they could really solve partial differential equations on computers in an iterative process; finite element analysis was just really being appreciated. Suddenly there was almost an infinite requirement for computing because it became so clear that the more steps you could do in your iterative solution, the better the answer would be, therefore in modeling something like weather or in the military applications modeling a nuclear reaction, all these things required the solution of differential equations where you could divide it into as many small units as you could imagine and you were limited by the computing power to do it at that level of sophistication.

An example would be right here in Colorado Springs, and I'm thinking back now only a few years when I was visited by people from the European Center for Medium Range Weather Forecasting, which I view as probably one of the very best modeling facilities in the world. They have a number of Cray Research Machines. We're talking about the unpredictability of the weather here and why did the weather simulation do such a poor job? They'll forecast sunny skies and it'll snow, as it just did. It wasn't forecast. They said, "Oh, well one reason probably is we don't recognize the Rocky Mountains. We just flatten them out.".

It gives you an idea of how far we have to go in sophistication before we can model the real environment because the Rocky Mountains clearly have some effect on the weather here. You can't just flatten them out.

DKA: This large-scale solution of differential equations was one of the big areas for getting a solution. Were you concerned at all about working with people who were setting up software for solving these problems? What was the conversation between you as a hardware designer and the people that were trying to develop the software to run on the machines which you were creating?

SC: Early on in my career there really wasn't much software. Hardware was built and it was "Good luck to you purchaser, you can now write a program to run on this machine." That, of course, ran into all sorts of problems; let's say in the 60's when customers felt they should have some say in software. The hardware company should provide some. So during that period of time, our compilers and operating systems began to be part of the requirement of delivering scientific computing equipment. It became a significant portion of the cost of building machines.

Today I think its fair to say that software costs exceed hardware costs in almost every large company. It has been an evolution in which software has had an increasingly larger and larger role until, well, in the case of the microprocessor; squarely software is 99.99% because the hardware is so simple.

From CDC to Cray

DKA: As Control Data developed as a company, you were more successful, you were selling more machines, how did that affect what you were doing in the company and the way you interacted with your colleagues?

SC: On a personal basis, as the company became more successful I became more and more distracted I guess would be the right word, by marketing activities, management activities, things not of a technical nature. My want to continue to do the technical work personally caused me to move out of town and since we were Minneapolis at that point. It occurred to me - Why not move back to the little hometown, which is only a short, drive away. Which is what I did. Built a building in Chippewa Falls, Wisconsin and essentially was able to start over doing the technical work without interruption because it was far enough away so that most of the customers didn't want to drive that far. Anyone who came must have really wanted to see it and therefore it was appropriate to spend time with him or her. It was a nice filtering process for the marketing organization.

That's how Chippewa Falls operation was started and when as you can imagine the evolution then, since I was so far away from the headquarters building, the communication dwindled until it was no longer perceived as that important. Financing became the issue. Funding wasn't available and so it was time to start a new company. That began Cray Research.

DKA: That was in 1972 wasn't it?

SC: '72 yes.

DKA: You present that as a simple story but that must have been a somewhat difficult transition to make.

SC: I'm never been bothered with these transitions and perhaps it is my own attitude but I always perceive them as being unavoidable. That is, all the other options have been eliminated and this is clearly the thing to do. So I've never laid awake at night wondering if I'd made the right career decision. It's not quite the same as moving from one company to another. In this case I'm viewing myself as being the company so when the environment that you're working in is no longer satisfactory, you look for a better environment. That means starting new company if indeed the structure of what you're working in isn't satisfactory any more. Those decisions that seem important with hindsight always seemed easy at the time.

DKA: Let's talk a little bit about '72, you're transitioning out of Control Data and starting a new company. How much of that had to do with issues of design of machines? I'm sure that part of the issue for Control Data was developing a customer base and continuing to work with those customers. Much of your design philosophy is often to go in new directions. Was that an issue at the time?

SC: It certainly was and it has to do with perception. In 1972 the perception was that there wasn't much market for big scientific computers any more. The market had been saturated. The thing to do was to expand into commercial areas. It's a very familiar story.

I was willing to accept that perhaps the market would be small and so if I started a small company that was very dedicated to this one narrow area and if I called it "Cray Research Inc." to emphasize the character of the company, there would be an opportunity because I could see Control Data discontinuing all those efforts and pretty soon I'd be alone again in the marketplace. That pretty well happened because Control Data did not follow through with new innovations in scientific computers, essentially left the marketplace to me. So I was able to repeat the scenario of starting again a small company at the right point time in the marketplace where few machines are significant and a few years later sure enough people began to perceive that maybe there was a market for large scientific computers again. So another cycle started.

Integrated Circuit Technology

DKA: What was the time like from '72, Seymour, in terms of the technology? We talked about the role of the transistor in shaping the 1604. As you started your own company once again, what did you see as the way to successfully build?

SC: There was a major event in terms of electrical components at that point in time. All of the machines that I designed at Control Data were based on discrete components and in 1972 there was an opportunity to use something called an "integrated circuit" which was a collection of devices all on one chip.

There was another basic threshold here. The first Cray Research machine designed from '72 to '75, I would guess, used an integrated circuit for the first time in my design career and this turned out to be very much more cost effective than putting so many little discrete components together. It was another major plateau.

DKA: What were the challenges that you remember about actually making that machine?

SC: Well, it was working with Fairchild Semiconductor who fostered and was spin-off companies at that point in time because they weren't quite sure how to use integrated circuits or what to make and we kind of had to negotiate what the mutual goal would be. So they ended up providing an integrated circuit for my particular wants as sort of a research project. That led to great things.

DKA: Did you find that many people on the market were in the business, I should say, were skeptical of the IC's when they first hit?

SC: No. They were skeptical about scientific computers and whether it was worth the larger amount of money to make them any more. I don't think that integrated circuits were an issue because they were being used in other electronic devices. One can regard what I was doing as a spin-off of the main thrust, which was to make more cost effective electronic devices, like radios, television sets.

Building Relationships and Credibility

DKA: In terms of setting up a company, obviously you need to bring people with you. You need to set-up a new environment. Who did you want to come with you at Cray?

SC: In terms of people, I needed the security that I didn't need in a technical area. I was willing to take lots of risks in a technical sense I wanted the security people I knew in starting a new company. I think you can understand that. You focus your risk on particular areas. I wanted the people that I'd worked with most of my lifetime to part of this project because I liked the relationships. I wouldn't have to spend my time working on the human aspects of the relationships involved because they were already established, therefore I could concentrate all my efforts in the technical area. One brings one's friends on these adventures.

DKA: How many of them were there?

SC: Half a dozen. Probably a dozen shortly thereafter. It was a matter of pirating from your former company. That would be the way to view it. In this case, it was not an issue because the former company would like to close it down as quickly as possible so there's no contest here.

DKA: And so most of those people had already been with you at Chippewa Falls when you had your separate laboratory as part of CDC?

SC: Yes. Essentially all of them were.

DKA: That must have been a heady time for you. But you seem to have this enormous sense of confidence in your ability to perceive this.

SC: I'm not sure its real confidence or the need to project confidence. I think one supports the other. I guess I have faith. That's a little different than confidence. I've been well taken care of in my lifetime. God looks after me so to speak and so if you have faith that you're doing what you're supposed to be doing, you're doing the best you can, then as I view it, you can leave the responsibilities for all of the peripheral aspects of life to someone else. So far that's worked for me.

DKA: You certainly had a well-established reputation at the time you set up Cray Research with the customer base in places like the National Laboratories in government places, in many universities. How did they respond, the people that you knew, and the customers to your new corporation?

SC: Initially it was a matter of credibility. As it still is today when you start a new company. The concern was "its not clear that this little company is going to survive and therefore, I don't see as a my job managing this government facility that I should take a risk on a product from this company that might disappear shortly". So there was this initial threshold of establishing the first order or two in order to get some credibility and get some concept of the user sharing the risk that they are taking collectively with a new company.

There was that hurdle and it was quite difficult for Cray Research in the 1974 - 1975 time frame when no machine had been delivered, we were running out of money, the stock market at that time was so bad, all of the advice of the investment bankers was "don't even try it". Relying on blind faith and trust I concluded if no one would be willing to finance a public offering, what we would do, is just do it ourselves. We offered stock without an underwriter and it was modestly successful, enough so that we could continue growing and deliver a product and credibility rises rapidly.

I suppose in a way it’s unfortunate this threshold is so steep for small companies starting but I suppose its necessary to prevent an endless supply of small companies. I think its no different today than it was twenty or thirty years ago in the sense that small companies have to get over this credibility threshold before they can get anywhere in the financial community.

Designing the Cray 1 With Aesthetic Appeal

DKA: We have a picture of a Cray 1 and if you can get that on camera. You might just want to say a few words about this design and what made it stand out and what was new and different about it.

SC: It was different I think in a couple of respects. It was the second vector machine in the marketplace, the previous one being done by Control Data. It had in integrated circuits in it for the first time. In the work that I had done and I've always been interested in the aesthetics, the appearance of computers. I don't know why other machines reflect that because I enjoy that part.

So many computer products are rectangular boxes and don't seem to have any aesthetic appeal as I viewed it. This was my first opportunity to deal with the aesthetics, go out of the way a bit, spend an extra 5% money perhaps to make something visually intriguing and so clearly this particular product was different than the rectangular boxes that were available from everyone else. I think it enhanced the early marketing opportunities for the machine. There is some emotional content even in buying large scientific computers and something that looks different and intriguing can sometimes sell a machine over competitors' square box.

DKA: So you want to say a bit about the sense of aesthetics of that particular design?

SC: I've enjoyed the aesthetics part of building computers because its any extra little thing you add that is clearly your own personality being projected in the product. The continuation of the Cray 1 aesthetics into the Cray 2 and the Cray 3 has been an ongoing extra enjoyment so to speak. It may cost a little more to build something with a bit more aesthetic appeal but it is not enough to make cost effectiveness difference. All I can say I've enjoyed doing that part of and I continue to. The Cray 3 and the Cray 4 will continue to show dramatic new visual impressions. Clearly more than a square box.

I long ago wondered whether I'd ever be able to build a computer smaller than a human brain for example. Just as a reference. I find here before the end of my lifetime a Cray 4 is indeed smaller than a human brain. The aesthetics of how you package it therefore provides you with new opportunities because here you're dealing with something quite small. Its liquid cooled.

Computing's Future with Biology

SC: An intriguing thing I'm almost sure you won't know is the liquid that we're using to cool our Cray 2's, Cray 3's, Cray 4's, is also used as artificial blood in human beings for people that are allergic or for religious reasons can't accept a blood transfusion. They can use the same fluorocarbon basically. They have to have a little more hygienic but basically the same fluid that we're using to cool our computers. So there are these little intriguing things let's say that we're coming closer and closer to a product that is similar to what was created by nature. I don't want to get carried away with that because clearly we're building mechanical devices, but I've been recently quite fascinated with the nanometer sized devices that are perceived for the future.

I recently attended a national workshop called "The Pedaflop Conference" in Pasadena. There we are projecting as a group for the United States government what will we be building in twenty years? Let's project what it will be. A pedaflop is a big number that comes after a Teraflop which comes after a Gigaflop. In other words it's ten to the fifteenth, which is a huge number. My view is that as machines become faster and faster they have to become smaller and smaller because we have basic communications limitations which are speed of light communication.

If I extrapolate as I did at this workshop, the sizes that we have now which are in the micrometer range, to what we should be doing to accomplish the goals twenty years hence, we have to be in the nanometer dimensions. Well nanometer devices are the kinds of things that proteins are made of. They are molecular sized devices and if one let's one's mind run on the subject and one thinks "well, we're going to build computers in this time frame that are molecular in size", then here we are suddenly face with the same dimensions and structures as we have in biological molecules. Will we be allowed as human beings to start structuring on a competitive size basis with living things? I find that pretty fascinating and I would say, "No, we probably won't be", except for the things that we seem to be allowed to do recently.

I'm thinking now of what's happened in the past year. None of my work but viewing the work of basic researchers who are on the fringes of biological studies but are attempting to do mechanical things. If you have read, as I have, weekly scientific reports, we have been able to build nanometer sized devices mostly related to working with biological things but things like copper wire which are nanometer sized wires which are molecular size plus the fact that we've been able to look into living cells in the sense of extracting very small things and observing them in a molecular level.

I find this whole area fascinating because I perceive the need to move into this realm. I know nothing about it yet it seems like we maybe allowed to proceed in this direction and actually work with molecular things. What makes it also interesting is all the work that we're doing is involving simulations with large computers. We're simulating molecules, the interaction of molecules, docking sites, in case of studies of human diseases for example. Were does the virus dock on the molecule? All of these things that used to be chemistry are now suddenly becoming mechanical, mechanical engineers so to speak can now understand chemistry on a molecular level. Chemists are becoming mechanical.

The whole concept of living things are digital as I think we all have to face now. They are truly digital. They are made of molecules, that we don't understand how they work but we're beginning to understand their physical properties. It’s a very exciting time coming. Very scary because we don't know what kind of mess we're going to get into here with biological tampering I would say is the right word. I certainly don't want to take any moral responsibility in this area but clearly humans are going to mess with it in the future.

DKA: It would be interesting to see that extension down to that level of magnitude as a natural extension of the kind of movement that you've followed throughout your career.

SC: Yes, it seems like the next step.

Reducing Distances in the Cray Line

DKA: Now early on this notion of making distances smaller was part of what you were doing even in Cray 1. What was the rationale of the design that was to reduce distances among components?

SC: Yes. The Cray 1 was clearly conical in shape so that the wires could all be on the short inner surfaces of the modules. That has continued with the Cray 2 and the Cray 3.

DKA: That's been successful as a design principle?

SC: Yes. It has been a successful design principle. What we clearly want to do is to eliminate the interconnecting wires entirely in future products. So that all the communication is in other structures so that we don't have to deal with connecting materials. In the case of microprocessors today, that's been accomplished.

DKA: One of the things that we glided over very quickly was this change to a vector strategy in computer design. Do you want to talk a little bit about that and how it factored into your new types of machines?

SC: Yes. 1972 timeframe was the beginning of Cray Research. I was leaving Control Data with an unfinished project, which was a multiprocessor system. Multiprocessors scalars interconnected solving a single problem. That was very aggressive and it was being done with discrete components which was causing it to fall behind schedule. There was an alternative to multiprocessing which was vector processing. In other words, instead of doing things in parallel in separate mechanisms, to organize them in streams and do them in a vector mode. Since I just struggled with the not massively parallel yet, but parallel structure, I thought here was a wonderful opportunity with a new company to look at the vector side of the conceptual world and try one of those. That was my first effort at vector-structured machines. It led to a whole other level of understanding for me.

DKA: Did you find any particular problems in moving down that road?

SC: No. It was a conceptual issue and it was a matter of learning. It was a personal learning experience.

DKA: So you set that as a task for yourself and you were back in the library?

SC: Back in the library, yes indeed.

Les Davis

DKA: One of the people that is often mentioned in connection with your computer development is Les Davis. You want to talk a bit about him, what your relationship was?

SC: Yes. We had a very good relationship surely from my standpoint and I think from his. He seemed not so interested in the original conceptualizing as in following through and making it really work. He was the person who derived satisfaction from taking a conceptual plan and implementing it and making it truly work. Since I was the starter and he was the finisher we made a great team for quite a long period of time. I wish we could still be doing it. We both have let's call them, paternalistic feelings with the people that we develop in our groups, however his was stronger than mine and so when I decided that Chippewa Falls had become overcrowded with computer people and it was time for me to leave he could not bear the thought. He felt he had to support the family of maybe 5,000 people at that point in time in a community of 10,000. Anyway, he felt the obligation to people that he had personally developed, brought along technically, brought along socially. He couldn't leave.

The conclusion I would have is he has more people, a larger portion people thinking than I do. I'm more interested in the thing. I could leave all the people, wish them well, "Does any one want to come along?", which was the question I asked literally the 5 or 6,000 people at that point in time. Surprisingly to me there were only about a dozen that said, "Yes, I want to come along.". The rest said, "The risk is too great. I don't know what's going to happen. I don't know whether you'll succeed or not. I got a nice job here. My family's here. My kids are in school here." And all the other reasons you could imagine why not to make a change, why not to take a risk. I was surprised because I viewed myself as an average human being and I'm finding that average human beings are not as much risk takers as I was.

DKA: You're talking about the move to Colorado Springs?

SC: Yes the move to Colorado Springs from Chippewa Falls. Surprisingly few people are willing to disrupt their whole lives and to be fair I suppose one has to say "Well, I chose this point in time for me to disrupt my life", whereas they weren't given that choice, they would have to do it at my point in time. That's a big difference.

DKA: One of the things we've talked about Seymour is the whole notion of vision and how visions attracts, draws, motivates. Do you think, in terms of your relationships with other people that you have a stronger sense of that future, the next step than the people that you work with? What's different about your relationship to your own ideas?

SC: I have trouble relating to other people and how they feel about themselves. Particularly since I'm not a people person. I don't know that I can really answer that. I can only speak for myself and the fact that other people don't seem to feel the same way for reasons that I don't think I can analyze. Part of the thing that I've had which I'm sure is unusual is the feeling of security in taking risks and moving on and that I've been successful in the past. I've accumulated financial reserves that prevent me from worrying about starving in the near future. Most people don't have the benefit of that accumulated financial material social value that they can point to as being an asset. I've just been fortunate to accumulate that and therefore take greater risks than I'd probably take otherwise. I wish everyone could be in that situation because if we could all take such risks, we could clearly move forward as a people much faster.

DKA: Talking a little bit more about your relationship with Les, now you first starting working with him where?

SC: At Engineering Research Associates in St. Paul, in the glider factory. Yes.

DKA: Did your relationship as conceiver and implementer take shape in that form even in the early days?

SC: I think so. He was a few years younger. He didn't have a college degree and so he felt comfortable in that one step behind position. I'm not using the right term here but in the supportive role his contribution was as great or greater than mine and is today. He is clearly the leader at Cray Research. I don't think I could describe the relationship any better than I have. It clearly was a symbiotic relationship. It was most enjoyable to me. We've been good friends throughout this whole period.

DKA: Now Seymour, I know you tend to work evenings. Did Les work the same time periods as you did?

SC: No, he was more concerned with being with the people. He worked during the day. He dealt with all the personality issues, the human want issues, the needs of the people that were getting the work done. You can appreciate how important that was to me. He made things happen not only through his own work but through the works of others. Where I was allowed to go off merrily having my goal at the technical issues.

DKA: So you would come in, in the morning and maybe chat with him about what you worked on in the previous evening?

SC: Well there was plenty of conversation. Our days did overlap enough for that.

DKA: I know that there have been other people and another person I wanted to ask you about was Steve Chen. his relationship to you as a designer and as someone that you worked with.

SC: That's kind of fascinating because we had no relationship at all. I think I only met him half a dozen times. This was a relationship more or less generated by John Rollwagen, at that time CEO of Cray Research, because he wanted to have a protégé and so he created one. I'm sure Steve has a lot of skills but they didn't relate to me. We had our competitive project but it was very much arm's length. He was doing his project and I was doing mine and there was no interaction.

DKA: So you really didn't work together.

SC: Not at all.

DKA: So he was brought in as taking a different direction at Cray.

SC: Well there was a need at that point in time for a younger person to take the leadership in a technical sense. There was a corporate want and a personal want on the part of John Rollwagen.

Decision Path to the Cray 3

DKA: We talked a little bit about your move down here to Colorado Springs and I know that relates some to the decision about what to do about the Cray 3 and how to go about developing that project. Do you want to talk more about what was the decision path that led to this new step in your career?

SC: Yes. This may sound very familiar. This could be sort of a broken tape. Because at the point in time that I'm moving to Colorado Springs with the new high risk Cray 3 Project, Les Davis is no longer working with me on this close relationship. He is proceeding with the evolutionary improvement of present products at Cray Research.

Here we are competing for corporate funds with the evolutionary approach, which has some risk but relatively minimal risk, and the high risk approach which as a corporation we can't count on. At this point in time, the corporation is big enough, quarterly profits are important enough, shareholders' interests, customers' interests all say "If you have to choose between these two approaches it would be better to choose the evolutionary one" which Les Davis was completely in charge of and control of and had great confidence in. That was the reason for the spin-off "Good luck to you Seymour in your new project", which I appreciated because I was given financial resources, very sizeable ones, the facility here.

It was a wonderful opportunity and I liked John Rollwagen's rationale. And few people in the company could understand this because few people think about corporations. Here was the opportunity for the shareholders of Cray Research in spinning off a subsidiary into another company and providing stock in both companies to the shareholders to have the opportunity to have both the high risk and the evolutionary low risk as part of the investment. They could decide which one to keep, which one to sell as individual shareholders. There was no damage done to the shareholder as conceived by John or conceived by me in spinning off this company. There was no loss and yet from a standpoint of a corporate bureaucrat there was a huge loss because good grief what if this little company succeeds and wipes us out? There were all of these kinds of things and look what we're giving away. I kind of enjoyed the real disparity in thinking of people at that point in time. I certainly agreed with John Rollwagen that it was the thing to do and that the shareholders for the most part I think understood that. Most of them sold the risky part right away, which is very appropriate.

DKA: Let's become more general about the whole subject of innovation and the story of this new spin-off makes me think some of the whole story that creation of the IBM PC and the IBM culture, separate culture, separate environment in which to do something that was new and took a different direction. You must have done some thinking about innovation in a corporate structure. You said people haven't thought much about corporations, but here there are several times in your career when you've had to create new companies.

SC: Yes.

DKA: What do you think it is about innovation, is it necessary to be in a small corporation? Can it exist in a larger company?

SC: Well I think this comes down to the basic way that we structure corporations in the United States and how we've developed our laws and protective systems and how we've developed the way of funding which is through private enterprise. As corporations become larger and the quarterly earnings become important it becomes harder and harder even though the company is large to just take great risks that may involve the profitability over the next two or three years for example as most of these projects that I have done would do.
It’s much more socially acceptable in our culture to have a new company take this risk than it is an existing company takes the risk. It seems rather strange but that's clearly the way it works.

To illustrate that point look at the way that a venture capitalist will invest in a small company with the kind of thinking he does versus in investing in a large company in which he's calculating the price earnings ratio every day. They're just two different things. We as a capitalistic financially driven country see two completely different things, the venture kind of money and the established income for little old ladies. They're just different and so when you try to mix them you get in trouble. Clearly large corporations like General Motors and IBM are really struggling with that aspect now because the need for creativity is obvious and yet the structure denies it. As a basic we've seen all these big companies come crashing down so to speak in terms of their direction because of this very fact as I see it. The basic character of large corporations prevents high risk.

DKA: Is the only way to do it for someone to take as much risk as you've taken personally in your career?

SC: I think so. I think the wonderful thing about the way we run things in the United States versus Japan for example. In Japan, clearly the government takes the responsibility for these high risks and they manage it. Here we rely on individual people to go and do it themselves. And yet we collectively as a society provide the funds for them to do that. So it works just fine. It's just a different way of doing it than a managed high-risk venture. I like the way we do it.

Working With Young People

DKA: Seymour if you encouraged young people that have worked under you at various phases in your career to take similar risks, to have this sense of innovativeness about them?

SC: Yes. Young people for the most part are willing to take more risks than older people and so I've continually developed a younger and a younger group relative to my own age as I've gone along. I enjoy working with young people because they have a lot of enthusiasm and most basically they don't know it can't be done yet. People who feel that they have the experience to make their own judgments as versus mine, this may not sound right but, if they don't think that its going to work they won't put the effort in, whereas a new person that has no experience at all "Well if you tell me its true it must be true because you did it before and therefore sure I'll try it". It's that aspect of young technical people that has been most enjoyable and I think many of them have certainly moved on and into the world with a feeling of self-accomplishment because they took those risks.

Again a wonderful opportunity in moving to Colorado was I left behind all those old fellows and got new young people here, which has its downside because it took about five years to train people. Most of them had never worked in a computer environment before and so there was a horrendous training problem, which took a lot of time and money in terms of the corporation.

As I look around now I'm very pleased with the group that has been sorted out during this period of time. The people that I now have here are all very compatible with each other and very proficient in their tasks, which you couldn't say, at the beginning of the project.

Pioneering Circuit Technology

DKA: We were talking about the technical aspects of the Cray 3 and the Cray 4, and what you saw as a new aspect of technology that you wanted to work on with those. Do you want to talk about that?

SC: In going from a Cray 2 design to a Cray 3 design, and this is in very personal terms; I was moving from using conventional silicon technology, the mainstream digital sort that was made in a factory that's making parts for all sorts of other things, to exploring basically new materials. In this case the material is gallium arsenide, which has been used for a couple of decades in communication. All our satellite relays are gallium arsenide because of the higher frequencies.

So it seemed to me that it was time to try to build a computer from these things, which were accepted now in the communication world, but had not yet been accepted in the computer world. This was a risk I thought should be taken because no one else was doing it. That is a bit of an exaggeration, there were some other efforts, but there wasn't a major, large, scientific computer effort, and that's what I wanted to do. I wanted to bring new circuit technology into to my own experience.

Another motivation was that as computers became faster and smaller, it turned out the communication between circuits was very much a pacing item. And if you don't have basically faster circuits, you can't make the machine faster no matter how small you make it. So I wanted to combine my perception of better communication technology with gallium arsenide technology circuits, with the smaller size, and faster speed goals, and so that seemed like a natural one.

In the case of moving from Cray 3 to Cray 4, which we're doing now, it was a matter of evolutionary improvement to reduce the size using the existing early primitive tools, low level integration for example, then move to high level integration and gallium arsenide, and to make the packaging smaller. So this is a continuation of trend, and it has seemed as though a generation of machines tend to take a high risk circuit approach, then there's an evolutionary phase, another high risk approach and then and evolutionary phase, which has sort of a natural period to it.

DKA: We actually have some components of these machines. I don't know if you want to indicate some of the things you're talking about.

SC: We'll here's a Cray 3 computer module and it's about 4 inches by 4 inches by 1/3rd of an inch thick. It is a very, very dense package in terms of the total content per unit volume, and it has a relatively low level of integrated circuit in it. The secret is that this is what is now called a multi-chip module. But it has 1,024 integrated circuits in it, which is a huge number compared to what most people think of in multi-chip modules.

So the innovation that I feel is present here, is primarily one of using a small physical size components, in an intimate, 3-dimensional arrangement, which requires packaging technology that doesn't exist commercially today. It was the packaging technology that was the challenge in doing the Cray 3 computer because there was no existing way to interconnect 1,024 integrated circuits in such a tiny volume with any existing packaging technique. So there were two high-risk ventures at once; one the circuit, and the other, the packaging. It turned out to be quite a challenge that took a lot of resources and time to complete.

The Cray 4 is evolutionary. I don't think I can really hold these up without something falling off, but here's the Cray 3 integrated circuit and the Cray 4 integrated circuit, a factor of 10 in level of integration.

DKA: You're actually doing much of that basic work here in Colorado Springs in your own facility, is that correct?

SC: Yes, we actually have a gallium arsenide foundry dedicated to this very narrow kind of product. We don't make communication equipment in our foundry. We don't make microwave stuff. We make only large computer chips, and therefore we're able to focus our effort.

I spend quite a few years working with gallium arsenide facilities elsewhere attempting to avoid the necessity for building my own gallium arsenide foundry. But I saw one failure after another, and after 3 failures I recognized the problem is that you can't do this in a general purpose facility, because you can't get the focus in your particular area of work. So it became necessary to make the investment in a dedicated foundry in order to accomplish the goal. There were too many other research areas going on in parallel in other facilities. I tried both domestically and in Japan. Japan it was with Fujitsu, domestically with Rockwell and with Gigabit Logic. Those were the three companies I worked with attempting to realize the goal, but just couldn't do it.

DKA: They just weren't specialized enough?

SC: They couldn't do what I wanted to do without specializing, and they couldn't specialize because that wasn't their primary goal in life.

Cooling the Cray

DKA: We should probably talk a little about the cooling aspect of your machines because they are somewhat unusual. Do you want to say a little bit about your movement to a liquid cooled machines and some of the risks of that?

SC: This risk dates to the Cray 2. There was no real need to make a change between Cray 2 and Cray 3, so we stepped back one generation at Cray Research. The Cray 2 used liquid immersion cooling, and at that point in time it seemed pretty far out because everyone of a technical nature could think of a lot of reasons why it wouldn't work. The circuit board would swell up, the circuits would leak, the fluid would become toxic if you had a fire, there were endless reasons why it shouldn't be done. Of course you know that would make me want to do it more than ever.

So, it turned out that it had a reward. The reward in the case of the Cray 2 and in all the subsequent machines is that when you cool the circuits with liquid, you're able to much better able to control the temperature of the circuit than if you cool it with air, because the air is going to vary in temperature widely over various parts of the machine and you're going to have hot spots and cold spots. So with liquid cooling we have just a few degrees difference from one integrated circuit to the other. And this thermal stability has its rewards in that you end up with a much more reliable machine. Once all the initial design problems were overcome in the Cray 2 machines, a process which took a number of years, the Cray 2's were very reliable, and I think very successful.

DKA: Is that an idea that you came up with, or somebody else came up and presented to you and you championed?

SC: I came up with it. I don't know how, but what I remember is that no one else thought it was a good idea and I was stubborn enough to proceed anyway. I had enough resources at that time to say, "We will do it this way!"

Maximum Risk = Maximum Reward

DKA: I want to step back a little bit and talk about the general environment in which you operated in from your days at ERA (Engineering Research Associates) to the present. It's certainly been a special time in the history of computing obviously, because you had been there for most of the history of the discipline. You talked about setting your sites on one direction and you followed a career that's has some evolutionary periods and revolutionary periods. Do you think that people who follow in this field are going to have a very different environment, or do you think that the type of strategy you pursued would be successful in any period?

SC: Well I assume it would be successful in any period. To say what you just said in a slightly different way perhaps, one of my guiding principles is don't do anything that other people are doing. Always do something a little different if you can. The concept is that if you do it a little differently there is a greater potential for reward than if you the same thing that other people are doing. I think that this kind of goal for one's work, having obviously the maximum risk, would have the maximum reward no matter what the field may be. So I don't see where my strategy for accomplishing goals is at all unique to the computing business, or the time period either, no.

"Here Come Artificial People"

DKA: We talked some about some of the innovations that you think will follow, what other thoughts do you have about the future of this industry?

SC: Well in terms of computing, it seems to me that we will move away from the concepts of doing calculations entirely, and will be dealing with strictly with devices that interact with people, almost as people interact with people. So this is a little scary, here come artificial people.

To some extent, computers are approaching this now where we will, more than we are now, be able to communicate with computers by talking to them instead of typing on keyboards. We will be able to get visual inputs and we will be able to provide interactions visually using our hands to communicate 3-dimensional information as in a virtual reality system. So clearly the computer is becoming more personal in the sense that we react with it as we react with other people.

One of the fascinating things will be how far this goes and how fast, and to what extent it affects our lives as people. Will we have our closest friends be computers? Clearly not as a first choice but there will be more time spent I think in terms of how we spend our day interacting with things that are somewhat personal. We're just beginning to see that now, and as I talk with people who are at the forefront of personal computers for the home, they envision them being as being a companion. You get up in the morning, and you talk to your computer. You review what things you had planned to do today, how you should go about them, what are the opportunities, what's going to be on television tonight and do you want to record them. Things that very much affect your personal life, and they will be all verbal interactions with machines. Kind of scary.

DKA: Following that thought, what is the extent that you use computers to do things that you used to do by hand, or do you still do most of your work with a blank piece of paper?

SC: No I do it with a personal computer. I don't really use my own computers to design other computers, although they are used to simulate, they are used to verify, but the personal computer today is powerful enough to replace the paper and pencil, and I do much better with the keyboard than with handwriting. It completely escapes me why anyone would want to use handwriting to communicate with a computer. Newton completely eludes me.

I'm very satisfied with the rapid escalation of computing power in the desktop. It's going to go on obviously for some time and it's a great vehicle for getting your ideas down in a form that is digital and reproducible.

DKA: You mostly work by writing your ideas in text form rather than drawing them out?

SC: Yes. I talk to myself through the computer. I ask myself questions, leave things to be looked at again, things that you would do with a notepad. It turns out today that it's much better today to do with a personal computer rather than a notepad.

DKA: There's a process of intuition in your work isn't there.

SC: Yes, I'm supposed to be a scientific person but I use intuition more than logic in making basic decisions.

DKA: So I wonder what the parallel is with those before you in the evolution of information technology, with the beginning of writing and things like that and the role of intuition.

SC: I think that if you look at historical scientists you will find them mostly using intuition. The really famous people had conceptual things that came out of the blue. Einstein for example, you know the story of the train going down the track and he went, "Aha!" It was intuition. It wasn't that he had this all figured out mathematically, not at all. He had the intuition first and then he made the mathematics to match it up. So I think if you go back in history, human intuition had a quality that leads you to revolutionary things. There is no good explanation for "How did you get this intuition? Where did it come from? What are the ingredients for intuition?" I have no idea. It's just a fascinating human characteristic.

Human Evolution vs IT Revolution

DKA: So much of the Computerworld Smithsonian event is focused around acknowledging and celebrating what has been going on in information technology, and I think it's in contrast to the root that is going back to the beginning, from people speaking and going to handwriting, and an evolution of what we're doing here. What do you think people have learned from information technology through the 1980's?

SC: Not much I would say. Our communication skills aren't much better than those one reads in ancient writing. Our thinking process is not that much different. All we have is better technical tools, and so my perception is that evolution of people is ever so much slower than the evolution of mechanical things at the moment. We're obviously at an exponential growth of mechanical devices and yet our bodies and our brains are not changing very fast. They can't.

We go through genetic improvement through selectivity or whatever cause you would like to choose, but it's a slow process that has been going on for millions of years, and how can we expect it to do anything in a decade or two? So one would expect, at least I expect, we will run into some troubles because of our lack of human development with respect to the tools we are now making. It seems so incongruous in a way because here we are now doing it, and yet we ourselves are not evolving very fast. I'm not sure I'm answering your question but I see this discrepancy between what is happening to our heads and what's happening to the environment we are creating for ourselves.

DKA: I see that. Can you talk about the need for information? You focused mostly on the scientific community, and it is about gathering information and processing that information, whether it's for the national weather service, or who knows what. Is there some connection in your sense as you go through designing and planning all this out, to what it might have been like back when Guttenberg was designing moveable type, Edison was playing with the light; do you have any sense of that?

SC: No. I've never thought of myself in the context of historical great peoples.

DKA: But look the result of what you've done.

SC: Yes. What strikes me is the information revolution that is so overwhelming. I get a weekly science digest that I read from cover to cover carefully because it gives me an hour of reading of what has happened in the past week. It's absolutely mind boggling that every week, not in my field but in molecular biology, astronomy, basic physics, you know those kinds of things, if one could only assimilate that information at the rate it was being generated, it would be a total experience I guess.

There's no way we as individuals can even scratch the surface of the information that is arriving daily from society in a technical sense, and yet I would like to. I would like to understand all these things that I'm reading about. The information available today, whether it's a highway or not, it's an experience that all those previous generations you talked about, had no opportunity to see.

DKA: Do you think the visual representation of information and our ability to think more visually, and to interact more visually, is close to being a fundamental change in what we're doing with information technology; more fundamental that what we've seen so far?

SC: Well it is in the sense that we have such finite lifetimes, and if you go back 100, 200 or 300 years, people spent a good portion of their lifetime just doing a calculation or a development of something manually. Now you can do it in an hour visually interacting with equipment. This expands so dramatically what you can do in a lifetime. It is clearly a revolution. It's not that our basic thinking process is any better but just the tools are so much better that we can accomplish things in an hour that took years before. Plus the communication and interaction we have with all the other millions of people we have in the world.

DKA: What is the name of the scientific journal you were reading?

SC: Science News. It's a nice quick overview of the multi-disciplines we have in science today. You can get it for I think 19 dollars a year, best buy in the world.

DKA: It seems like reading that journal is much like what I have learned about information technology while talking with you today, that it is multi-disciplinary.

SC: Yes, it's the want to know. We have today such an opportunity to know more things than we can possibly learn in a short period of time. I think it's a wonderful time. Basically I have been describing my perception of 20 years from now having just come from a workshop on that subject, where we discussed at the rate we are going, we are going to have to be dealing with molecular dimensions, and working in a molecular world, in terms of devices. That is about as much as I can project. What that means for how we live and act 20 years from now, I don't know. I have great difficulty seeing in the future.

Geometric Progress in Computing

DKA: In the 1950's you were computing, talk about the differences in the methods of computing in the 1950's and now with the Cray 4. How can someone who is not familiar with this get a sense of the scale of the business from when you entered the field to today?

SC: We're certainly accelerating the pace geometrically of what we're able to do. But I don't see that the basic thinking is any different. I was trying to describe that by saying that our heads aren't keeping up with our tools.

DKA: I was thinking more of the strict numbers of computations. What's the scale of that?

SC: If you do that, it does seem that we are progressing geometrically. My perception of current rate is that we're doing 4 times greater computation, whatever you want to call it, every 4 years. Another way of saying it is, it is doubling every 2. I say it that way because we have about a 4 year cycle of building equipment, but every 4 years we build equipment that is 4 times as capable for the same dollars. There was an extrapolation of that curve 20 years hence, which comes up with pedaflop numbers. I'm not at all alone in this area, this was a group activity that came up with this conclusion that we would be dealing with these numbers in this timeframe. So what that means to how we use the tools, that completely escapes me now. Obviously we can solve some scientific problems that way, but what impact that has on how we interact with our tools, I can't say.

DKA: And you really don't see any impediment to reaching that goal?

SC: Not really. We see impediments to going beyond what we're doing at the moment but if one looks back in time, the rate has not changed over a couple of decades. We're moving forward exponentially.